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COSTS OF BEST MANAGEMENT PRACTICES AND ASSOCIATED LAND FOR URBAN STORMWATER CONTROL

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ABSTRACT

New methods are used to evaluate stormwater controls and Best Management Practices (BMPs) within a land development context. Costs are developed using published literature and standard cost estimation guides. A method is developed in which costs are determined for each parcel within a development for specific land uses. The effect of including the opportunity cost of land in the analysis is evaluated. Costs attributable to stormwater controls are allocated among purposes. A method is developed in which stormwater control costs are assigned at the parcel level. Data gaps and research needs are then explored in the context of addressing this complex problem.

KEYWORDS

Costs, cost estimate, sewer, urban stormwater management

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INTRODUCTION

Urbanization has resulted in increased stormwater flow into receiving waters, increases in flood peaks, and degraded water quality. Initially, stormwater management focused on easing flooding. Conveyance pipes and detention facilities were used for this purpose. With increased understanding of nonpoint source pollution, which has traditionally included stormwater sources, a holistic design of urban stormwater management systems needs to incorporate the multiple purposes of controlling major and minor floods, as well as stormwater pollution. These controls and Best Management Practices (BMPs) can be expensive. For example, the present value of the cost of retrofitting water quality controls for the Atlanta Metropolitan Area alone has been estimated to be about $1.5 billion (Law 2000).

It has been suggested that implementing source controls at the onset of development is more cost-effective. Unfortunately, data on costs and performance of these land-intensive controls are lacking. Available cost information indicates that a significant portion of the costs depend on site-specific factors. Additionally, the multi-purpose wet-weather flow control systems may have somewhat conflicting goals. For example, a combined sewer system provides the dual purposes of transporting wastewater and stormwater. Storm drainage systems provide local flood control but also are a source of water quality problems and degrade downstream receiving waters. Stormwater detention systems serve as both quantity and quality controls. Streets transport stormwater in addition to their main function as transportation conduits. Heaney (1997) proposed apportioning the costs of a multi-purpose facility by designing stormwater systems meeting each single-purpose goal, and dual and multiple purpose goals. Then the cost of the cooperative facility that meets all required goals is apportioned among the purposes using cooperative *n*-person game theory.

The life-cycle costs of a stormwater control facility include the initial capital costs and the present value of annual operation and maintenance (O&M) costs that are incurred over time, less the present value of the salvage value at the end of the service life. Capital costs include construction, easements and land acquisition, exploration, and engineering planning and design costs, and any additional costs for environmental mitigation. Because the value of land is site specific, typically only construction costs are included in the analysis. Moss and Jankiewicz (1982) promote the use of life-cycle costing to determine the best type of storm sewer pipe to buy. They point out that the length of service life is difficult to estimate due to the variable material durability, in-place structural durability, abrasive characteristics of the drainage, and corrosive characteristics of both ground water and drainage. In a case study for Winchester, Virginia, service lives for reinforced concrete, aluminized-steel corrugated pipe, and asphalt-coated galvanized steel pipes were estimated to be 75, 25, and 20 years, respectively (Moss and Jankiewicz, 1982). While life-cycle costing is an essential part of a cost-effective evaluation of various stormwater control systems, data on O&M costs are seldom available on a comprehensive basis, and were not part of this study.

This paper focuses on the life-cycle costs of on-site stormwater control facilities. The opportunity costs of land are also estimated and included in this analysis. Unless indicated otherwise, all costs are expressed in terms of January 1999 dollars based on the Engineering News Record Construction Cost Index (ENR CCI) of 6,000 (Engineering News Record, 1999). The methods are applied to a hypothetical urban area called Happy Hectares.

COST ESTIMATION METHODS

The traditional way to summarize cost estimating data is to approximate the total cost using a single variable power function as shown in Equation 1. This power function is linear in the log transform. The two parameters can be estimated from a log-log graph or found using linear regression on the log-transformed data, or using nonlinear regression on the untransformed data.

$$C = \alpha_0 x^{\alpha_1} \tag{1}$$

where: C = total cost, \$,

x = independent variable that is some measure of component size,

α_0 = coefficient, and

α_1 = exponent.

The exponent, α_1, represents the economies of scale factor. If α_1 is less than 1.0, then unit costs decrease as size increases. A generic economies of scale factor that has been used for years is α_1 = 0.6 (Peters and Timmerhaus 1980). When α_1 = 1, the power function simplifies to a linear relationship and no economies of scale are present. If α_1 >1, then diseconomies of scale exist.

A key reason for the popularity of the power function approximation is that it offers a way to replace a cost database with a single equation. This feature was very important before the widespread use of computers. The negative side of this simple approximation is that the fit may be inaccurate. Also, total cost is seldom a function of only one explanatory variable. For a multiple explanatory variable case, the cost estimating problem can be expressed in a general form as:

$$C = f\left(x_1, x_2, \ldots x_i, \ldots x_n\right) \qquad \textbf{(2)}$$

where: C = total cost, and

x_i = ith independent variable.

If a database of total costs as a function of n explanatory variables is available, an approximating equation can be developed using a variety of multiple regression approaches. The drawback to this approach is that the relationship of total cost to several explanatory variables is seldom this simple.

Recently, the U.S. EPA funded a research project in which the methods and data for estimating capital costs for stormwater facilities were evaluated and data were collected (Fan et al. 2000, Heaney et al. 1999a). A summary of the capital cost functions obtained from this analysis can be found in Table 1. Data for estimating capital costs for pipes, manholes, and pavement were obtained from R.S. Means (1996a) and based on the methods described in Dames and Moore (1978) and Grigg and O'Hearn (1976). Data on capital costs for storage facilities can be found in U.S. EPA (1993). Data on capital costs for BMPs can be obtained from Young et al. (1995), Schueler et al. (1992), and ASCE (2001). Of these sources, the data on BMPs is probably the least reliable. Some ongoing research projects are underway to improve the database of life-cycle costs and performance of BMPs. An internet database which describes the various BMPs can be found in ASCE (2000); a summary of the cost and performance data for selected BMPs was recently published in ASCE (2001) The State of California Department of Transportation, Caltrans, is sponsoring ongoing research in which individual BMP life-cycle costs and performance are intensively tracked over a period of several years (Caltrans 2000). The results of these research projects may enable BMPs to be more easily selected based upon site-specific factors, with a set of costs and performance criteria.

CASE STUDY-LAND COSTS

As part of the literature review, several case studies on urban stormwater design were evaluated. The selected case study is contained in a book on sewer design by Tchobanoglous (1981). This textbook subdivision design problem was adapted to allow for multiple land uses, and is shown in Figure 1. Tchobanoglous develops the calculations for designing sanitary and storm sewers for the same study area. The total area is approximately 43 hectares. The highest part of the drainage area is on the south side. All drainage ultimately goes to a local brook. The layout of the storm sewer system is also shown in Figure 1. The entire study area is divided into 54 sub-areas that range from 0.3 to 1.4 hectares in size. A parcel-level Geographic Information System (GIS) was developed to assist in the analysis (Sample et al. 2001). The GIS allows the designer to query information on the parcel level that can be used in the cost and optimization analysis. The right of way characteristics are shown in Table 2. The attributes of the residential, commercial, apartments, and school land uses are described in Table 3.

A spreadsheet was designed to incorporate all of the necessary information to perform trial and error design, based upon the methods developed by Miles and Heaney (1988) and refined in Heaney et al. (1999b). The hydrologic analysis used in this procedure is based upon the Natural Resources Conservation Service (NRCS) methodology, which is easily adaptable to the GIS, by assigning curve numbers (CN) to appropriate land uses and control options. Urban storm drainage designs are usually sized to handle a 5- or 10-year storm. Flood control systems are typically designed to provide protection for the 100-year storm. For this example, a five-year recurrence interval is used for the calculations. A key component of the capital cost of control options is the value of land. However, much of the current cost information does not include this component (ASCE 2001). Including land cost presents unique challenges in allocating costs appropriately by function. The following sections describe a method for including land costs in selection of BMPs. For more detail, the reader is referred to Heaney et al. (1999a).

Parcel-level cost analysis

Real estate appraisers estimate market value, which can be defined as (Boyce 1981):

> *The highest price in terms of money which a property will bring in a competitive and open market under all conditions requisite in a fair sale, to the buyer and seller each acting prudently, knowledgeably, and assuming the price is not affected by undue stimulus.*

The present value of a series of future annual income is:

$$PV = A\left[\frac{1-(1+i)^{-n}}{i}\right] \qquad \textbf{(3)}$$

Where PV = present value, \$,

A = annual income, \$/year,

n = number of years, and

i = interest rate per year.

As n tends to infinity, equation 3 becomes:

$$PVC = \frac{A}{i} \qquad \textbf{(4)}$$

Where

PVC = capitalized present value of an infinite stream of future benefits.

The present value of an infinite future stream of earnings is called the capitalized value of the future income stream. For example, a detailed investigation of the rate of return for muck farms north of Lake Apopka in Florida revealed an expected annual return of about $1,137 per hectare (Heaney 1994). Using a discount rate of 10 percent, the expected present value of this land would be $11,367 per hectare. Detailed studies of comparable muck farm land indicated an average selling price of $11,119 per hectare, very close to the farm budget analysis.

Urban land use does not have a metric similar to crop productivity. However, a reliable estimate of urban land value can be obtained by viewing the urban development as an investment opportunity. The first step is to calculate the investment in raw land and its improvements exclusive of the building. The next step is to assume a reasonable return on investment, say 6 percent. Thus, the annual benefit of committing this parcel of land to this use is 6 percent of the investment. The land is assumed to hold its value over time. Therefore, the present value of the future sales price equals the original purchase price. In summary, the urban cost of committing land to this use is the opportunity cost, which is estimated as the investment cost times the rate of return.

Transportation Cost

Much of the cost of urban stormwater infrastructure can be attributed to providing automobile access. A relatively large literature is directed at estimating the true costs of various forms of transportation, particularly automobile-related transportation. Litman (1998) summarizes this literature and recommends methods for properly estimating the transportation costs. Heaney et al. (1999c) quantify the impact of the automobile on urban land use in general, and urban stormwater systems in particular. Accommodating the automobile requires committing a major portion of contemporary urban systems for streets, driveways, parking lots, garages, etc. Some costs of providing land for transportation are paid by external subsidies from the state and federal governments. Much of the costs of local streets and parking systems are paid by property and sales taxes. Thus, virtually none of these costs are directly assessed on the user. This assignment of transportation costs is in stark contrast to a water utility wherein the total cost is assigned to the users. Much of the cost for water utilities is in the form of commodity, or demand charges, so that consumers are aware of the full cost and have direct incentives to reduce their demand. For the purposes of this discussion, assume that a transportation utility exists in the urban area. This utility is responsible for all aspects of transportation and parking. It must pay full costs for its network including land costs and levies this cost directly on the transportation users.

Litman (1998) defines roadway land value as follows:

> *Roadway land value costs include the value of land used for rights-of-way and other public facilities dedicated for automobile use. This cost could also be defined as the rent that users would pay for roadway land if it were managed as a utility, or at a minimum, the taxes that would be paid if road rights-of-way were taxed.*

Housing (Construction and Land) Cost

It is instructive to trace the development of raw land into housing or other uses and then estimate the investment in raw and improved land. Dion (1993) provides a breakdown on the components of cost for a typical house built in 1991 as shown in Table 4. Finished land and labor/materials constitute 75 percent of the total cost. If the overhead and financing are prorated to the land and the house, then the land cost constitutes about 29% of total costs. The Urban Land Institute (1989) presents another breakdown of land development costs for 1984 and 1988 as shown in Table 5. A rule of thumb in the home construction industry is that the cost of the house should be about twice the cost of the land. Thus, land costs are assumed to be 50% of construction costs.

A breakdown of housing costs by function for a typical medium density residential house is shown in Table 6. The total construction cost for the house is $87,900. The total land value is estimated to be 50 percent of the cost of the house. Each component is then allocated its value based upon the proportion of area that it occupies. Unimproved land is assumed to be 2/3 of the total land value. The costs of improvements for water, wastewater, and stormwater are estimated for each functional unit. For example, all of the wastewater costs are assigned to the house. Landscaping costs depend upon several factors, including opportunity costs, soil preparation costs including topsoil, sod, and soil conditioners, and an irrigation system. In order to determine the opportunity cost, a land valuation analysis must be performed for each land use. A land valuation analysis for a medium density residential lot is presented in Table 6. The area of each component of the medium density lot is listed in column 2 of Table 6. The percentage of each component is calculated in column 3. An estimate of the cost in $\$/m^2$ is found in column 4. By multiplying the values in column 2 by column 4, the construction cost is calculated and is shown in column 5. Next, the percentage in column 3 is multiplied by the total of column 6 to estimate the land cost breakdown in column 6. Column 7, the unimproved land cost, is obtained by multiplying the values in column 6 by 2/3. Using this calculation, the value of the 334.5 m^2 of land for the yard function is $26,370.

<u>Landscaping Cost</u>

Next, the procedure for calculating opportunity costs for landscaping must be developed, as illustrated in Table 7. The value of $26,370 is annualized, using an interest rate of 6%, and an infinite term (as in Equation 4), to obtain $1,582/year. Then, the present worth of 25 years of annual costs of $1,582/year is calculated using an annual discount rate of 6%, to obtain $20,226. Dividing this value by 334.5 m^2 gives $\$60.50/m^2$. This value per square meter is used for all grass types because the underlying land value is assumed to be constant regardless of the grass type. Landscaping costs were developed from RS Means (1996b), updated to January 1999, and are included in Table 7 (for a medium density residential lot). The initial capital investment consists of soil preparation costs including sod, topsoil, and soil conditioners and an irrigation system. For the “good” lawn, the present value of the initial landscaping investment is $23.90/m^2. Costs for lesser quality lawns drop to $18.40/m^2 and $10.20/m^2 for fair and poor quality lawns, respectively. For the good lawn system, operation and maintenance costs add an additional $15.70/m^2, bringing the total to $100.20/m^2.

Portion of Total Cost Attributable to Stormwater Quality Control

These unit cost estimates are preliminary in that the proper definition of costs depends on the alternatives providing “equivalent” levels of service. For example, consider the following three options for a 557.4 m^2 lawn:

- Conventional lawn with a sprinkling system
- 278.7 m^2 of conventional lawn and 278.7 m^2 of forest
- 185.8 m^2 of conventional lawn, 185.8 m^2 of forest, and 185.8 m^2 of swales.

While it is possible to estimate the cost of each of these three options, the customer must view these options as providing the same level of service in order for them to be equivalent. If the customer strongly prefers the conventional lawn, then it is inaccurate to select other options based on lower cost if they are not perceived to be equivalent. Further work is needed to provide more accurate assessments of equivalent landscapes. For this analysis, the customers are assumed to be indifferent regarding the available options and simply select the least cost combination of BMP controls. An estimated 10 percent of this total cost is allocated to stormwater management. This number is admittedly arbitrary but it represents our best guess at a reasonable value to assign to stormwater management.

Similar estimates were made for “fair” and “poor” lawns. The resulting total costs attributable to stormwater vary from $7.50/m^2 (poor) to $8.70/m^2 (fair). Better lawns are preferable from the viewpoint of being able to store more water. However, they also cost more. A linear programming model was then used to find the least costly mix of alternatives (Heaney et al. 1999b).

Similar land valuation estimates were made for low density residential lots, commercial, apartments, and schools. An analogous procedure was followed for these uses, except that the commercial, apartments, and schools were aggregated into single lots, respectively. These valuations can be found in Table 8 for low density residential, commercial, apartments, and schools.

Typically, land value is not included in the analysis of cost of WWF systems. However, it is essential to include this cost. The amount to be charged should be based on the opportunity cost of the land. This land value is an essential part of the analysis since most of the on-site or neighborhood BMPs are land intensive, e.g., detention systems, functional landscapes. The incidence of these costs is also a critical factor as a possible incentive to customers for providing on-site controls and as an accurate assessment of their fair share of the total cost.

The customers of the urban WWF system can be viewed as the individual parcels served by the system. However, this taxonomy ignores perhaps the largest generator of urban WWFs, which is, runoff from transportation land use, especially during micro storms. Right-of-way land use comprises about 25 percent of total land use. However, it constitutes a disproportionately large amount of the directly connected impervious area that is the major source of runoff from small storms. Transportation systems also constitute a major portion of the WWF quality loads. Thus, transportation systems should be included as separate customers in order to evaluate their share of the cost of the WWF system.

Pavement and concrete costs must be included in this calculation. These costs were estimated based upon unit costs developed from R.S. Means (1996a) for various right-of-way widths, and per m^2 costs which are $\$37.30/m^2$ for curbs, $\$12.90/m^2$ for pavement, and $\$3.20/m^2$ for sidewalks and patios. Since the area of each paved surface is known, the total cost can be obtained by multiplying estimates of the imperviousness area. Alternatively, the length (for right-of-way uses) may be multiplied by the unit cost factors ($/unit length) for each right-of-way. The rights-of-way identified in Figure 1 were assigned widths based upon the following criteria:

- most streets within the development have a 15.2-meter (50-foot) right-of-way,
- the minor arterial has a 18.2-meter (60-foot) right-of-way, and
- the major arterial has a 21.3 meter (70-foot) right-of-way.

The total right-of-way costs are not just a function of pavement costs. There is an opportunity cost to devoting land for rights-of-way instead of to development. Several different methods could be used for determining the value of the right-of-way; the one selected here is to use the lowest valued land use, which is the opportunity cost for undeveloped land for low density residential use, or $37.60/m^2. This method is consistent with marginal cost analysis. Several street profiles were analyzed. Street 1 is a standard street with curb and gutter. Street 2 is a street with porous pavement and curb and gutter. Street 3 is a standard pavement street with swales. Street 4 is a street with porous pavement and swales. Because the right-of-way must remain constant, the travel lane was reduced in the case of streets using swales. These costs are added to the opportunity cost and apportioned to stormwater as shown for all rights of way in Table 9. Streets with better infiltration characteristics are more expensive. The same LP model as presented in Heaney et al. (1999b) selects the least costly mix.

The costs of parking, sidewalks and patios, and driveways were determined using a similar procedure. Parking lots were evaluated in the following forms: standard pavement, and three types of porous pavement of gradually increasing permeability. The cost increases with the increase in permeability of the parking area. A ratio of 5% was used to apportion the costs to stormwater. Two types of sidewalks and patios were evaluated, standard and porous. The results of this analysis are summarized in Table 9. Again, as the infiltration performance increases, so does the cost. The two types of driveways evaluated were standard and porous, as shown in Table 9. As with the sidewalks, costs increase as the permeability increases.

Next, runoff volumes were calculated in terms of the difference in volume between the pre-and post- development scenarios. BMP control costs are estimated in $/m^2. These costs are assumed to be the incremental costs over and above the costs of conventional systems.

Using the procedures developed previously, unit costs for various control options were estimated for eight different land uses: low and medium density residential, commercial, schools, apartments, and 15.2, 18.2, and 21.3 meter (50, 60, and 70 foot) rights-of- way. These unit costs, including opportunity costs, are listed in Table 9. An alternative analysis was performed excluding the effect of opportunity costs. These results are presented in Table 10.

Using $53.80/m^2 in Tables 9 and 10 results in a spread of from $0.19-0.71 per liter of storage. Costs for aspen and woods are estimated based upon typical landscaping costs, and the computed $/liter unit costs were compared with

Schueler (1992) and U.S. EPA (1993) for reasonableness. The incremental cost for roofs is based on the added cost to direct this runoff to the appropriate pervious area, the value of which was checked for reasonableness. The values computed fell within acceptable ranges from these references, adjusted upwards to bring them to the same time scale.

The results of the optimization can be found in Heaney, et al. (1999b) and are summarized in Figures 2, neglecting opportunity costs, and Figure 3, including opportunity costs. The optimal total system cost, including land opportunity costs for Happy Hectares, is $4.2 million (this result has been adjusted to reflect costs in the Denver/Boulder, Colorado area). The total system cost, neglecting opportunity costs, is $3.9 million. This represents approximately between 14% (including the effect of opportunity costs) and 16% (neglecting opportunity costs) of the total $26.6 million investment neglecting opportunity costs, and $30.8 million investment including opportunity costs. A key issue is that the allocation of a fixed percentage of costs to stormwater control needs to be further evaluated. More work needs to be done to estimate the appropriate allocation of costs to stormwater control for a multi-use land feature element.

SUMMARY AND CONCLUSIONS

Virtually all of the cost estimates in the literature are based on the conventional approach of fitting regression equations to cross-sectional data on as-builts. These approaches were the only viable alternative until the widespread availability of microcomputers. Until recently, research in the site-specific design factors of BMPs and other control options for wet weather flows has not been done. This paper presents a possible general methodology to analyze and use this information on a development scale level, which the authors argue is an appropriate scale for this analysis.

The following conclusions and recommendations are evident from this research:

1. A process-oriented approach to cost-effectiveness evaluations appears to be more appropriate for evaluating distributed stormwater controls than are methods based on simple power function cost curves. Curve fitting approaches to cost estimating are usually based on a very limited number of explanatory variables and do not reflect the wide variety of factors affecting total system costs for these systems.

2. The unit cost data provided by companies such as R.S. Means are a valuable source of the necessary cost data and should be an integral part of the overall cost-effectiveness evaluations.
3. This method needs to be expanded to include on-site controls such as infiltration. Such an analysis is not simple since storage routing is required at the parcel level in addition to evaluating larger storage systems.
4. A database of flow and quality monitoring for small (40 hectares or less) catchments is needed to evaluate actual system response for small drainage areas. These catchments can be used for overall cost-effectiveness evaluations.
5. The benefits of urban stormwater systems need to be better quantified. Flood damages are relatively easy to estimate. However, stormwater quality control benefits are more elusive.
6. The overall system evaluation should include structural and non-structural BMPs as well as conventional storm drainage systems.
7. A defensible method is needed to allocate costs among the many uses of developed land, of which distributed stormwater control systems is one. The land development costs attributable to stormwater management is a research need.
8. Downstream receiving water impacts should be included in the evaluations.
9. A combined sewer design should be evaluated and its cost apportioned among wastewater and stormwater. The effect of providing additional storage in the combined sewer should be evaluated.
10. The cost optimization should be refined to take into account both the broader land use optimization and cost allocation to the level of each land use, and subsequently to each parcel. Combined with GIS, this analysis should be performed for several different scenarios (micro storms, minor storms, and major storms).
11. The impact of streets and parking as integral parts of the urban stormwater system needs to be evaluated. Streets and parking comprise the majority of the directly connected impervious areas for stormwater systems. Hence, they are a major source of the problem. However, they also comprise an essential element of the stormwater management system, especially during periods of very high runoff when the sewers are overloaded. A significant part of the cost of streets and parking is for drainage. This cost needs to be included in the overall cost of stormwater management systems. A preliminary attempt has been made here to quantify deleterious impacts from micro storms. More work is needed to identify these impacts, and

assess an allocated, life-cycle cost of mitigating them.

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Table 1: Capital cost functions for selected wet-weather controls***

Item	Equation	Explanatory variable	Source
CMP drainage pipe	$C = 0.5262D^{1.3024}L$	D = Diameter in cm L = Length in m	R.S. Means (1996a)
RCP pipe	$C = 0.1368D^{1.6259}L$	D = Diameter in cm L = Length in m	R.S. Means (1996a)
Manholes	$C = 1458H^{0.9317}$	H = manhole height in m	R.S. Means (1996a)
Surface storage	$C = 1.515*10^{6}V^{0.826}$	V = volume of storage in M liters	U.S. EPA (1993)
Deep tunnels	$C = 2.162*10^{6}V^{0.795}$	V = volume of storage in M liters	U.S. EPA (1993)
Detention basins	$C = 2.195*10^{4}V^{0.69}$	V = volume of storage in M liters	Young et al. (1995)
Retention basins	$C = 2.247*10^{4}V^{0.75}$	V = volume of storage in M liter	Young et al. (1995)
Infiltration trenches	$C = 1482.864V^{0.63}$	V = volume of voids in m^3	Young et al. (1995)
Infiltration basins	$C = 178.967V^{0.69}$	V = volume of basin in m^3	Young et al. (1995)
Sand filters*	$C = K_1A$	A = impervious surface in hectares	ASCE (2001)
Grassed swales**	$C = K_2L$	L = length of swale in m	ASCE (2001)

*K_1 is a constant ranging from 27,700-55,300.
**K_2 is a constant ranging from 16.4-45.9.
***Costs in 1/99 $. None include cost of land acquisition.
Note: Significant figures are necessary due to metric conversion, and do not imply the equivalent accuracy in the result.

Table 2: Right-of-way characteristics of Happy Hectares

R/W m	Length, m	Curb m	Parking m	Landscaping strip, m	Sidewalk m	Traffic Lanes, m
15.2	8,741.8	1.2	2.4	3.0	2.4	6.1
18.3	342.6	1.2	4.9	3.0	2.4	6.7
21.3	835.5	1.2	4.9	5.5	2.4	7.3

Table 3: Lot characteristics in Happy Hectares

Land Use (residential)	# of Parcels	Roof Area m^2	Patio m^2	Driveway m^2	Land-scaping m^2	Total Area m^2
Medium Density Residential (14.8-19.8 Dwelling Units/Hectare)	255	1,600	18.6	55.7	334.5	557.4
Low Density Residential (4.9-12.4 Dwelling Units/Hectare)	51	2,000	37.2	74.3	910.5	1,207.8
Land Use (non-residential)	**# of Parcels**	**Stories**	**Parcel Area m^2**	**Roof Area m^2**	**Parking Area m^2**	**Land-scaping m^2**
Apartments	2	2	15,113.8	4,359.8	6,975.6	3,778.5
Commercial	6	1	44,694.0	14,199.6	28,306.2	2,188.2
School	3	1	13,880.7	6,417.9	4,813.1	2,649.8

Table 4: Breakdown of the cost of a typical house, 1991$ (Dion 1993).

Item	% of Total	Amount, $
Overhead/Profit	20	$24,000
Financing	5	$6,000
Finished land	22	$26,400
Labor/materials	53	$63,600
Total	100	$120,000

Note: For the convenience of the reader, the ENR Construction Cost Index (CCI) of 1991 is 4835.

Table 5: Breakdown of the cost of housing in 1984 and 1988 (Urban Land Institute 1989).

Item	% of development 1988 $	% of development 1984 $
Raw land	19.3	17
Land improvements	12.6	7
Financing	4.4	6
Labor	17.4	18
Marketing	4.3	4
Materials	24.1	29
Overhead	6.5	7
Profit	8.1	9
Advertising	1.2	2
Other	0.4	2
Total*	98.3	101

*Note: The totals do not sum to 100 in the source.

Table 6: Land valuation for medium density lot, 1/99$.

Component	Area m^2	% of total	$/m^2	Construction Cost, $	Total Land $*	Unimproved Land, $**
Roof-house	111.5	20.0%	5.20	$67,500	$8,790	$5,860
Roof-garage	37.2	6.7%	3.20	$13,600	$2,930	$1,953
Driveway	55.7	10.0%	0.40	$2,400	$4,395	$2,930
Yard	334.5	60.0%	0.10	$3,600	$26,370	$17,580
Patio	18.6	3.3%	0.40	$800	$1,465	$977
Total	557.4	100.0%		$87,900	$43,950	$29,300

*Total land value = 0.5*construction cost.
**Unimproved land value = (2/3)*total land value.

Table 7: Cost analysis of landscaping for medium density lot, 1/99$

Item	Input Data	Good $/m^2$	Fair $/m^2$	Poor $/m^2$
A. Initial Capital Investment				
1. Soil preparation				
Initial cost of sod		$4.60	$3.70	$2.80
Initial cost of topsoil, 15 cm		$5.40	$4.30	$3.20
Spreading topsoil, 15 cm		$6.90	$5.50	$4.10
Soil conditioners		$0.30	$0.20	$0.10
Sprinkler system		$6.70	$4.70	$0.00
Sub-total		$23.90	$18.40	$10.20
2. Opportunity Cost of Land				
Land investment cost, $	$26,370			
Opportunity cost investment rate	6%			
Annual cost, $/yr.	$1,582			
Interest rate per year	0.06			
Present worth over 25 years, $	$20,226			
Present worth, $/m^2$,		$60.50	$60.50	$60.50
Total of initial capital investment		$84.40	$78.90	$70.70
B. Operation & Maintenance Costs, $				
Lawn watering				
cm per year	129			
% of pervious area that is irrigated				
Cost of water, $/1000 L	$0.40			
Present worth factor	12.78			
Present worth		$2.60	$1.60	$1.00
Lawn maintenance				
Weeks per year	26			
$/week	$8.46			
Maintenance area, m^2	267.6			
Present worth		$10.50	$5.40	$3.80
Sprinkler system maintenance		$2.70	$1.60	$0.00
Total operation and maintenance costs		$15.70	$8.60	$4.70
C. Total Cost		$100.20	$87.50	$75.50
Portion attributable to stormwater control				
Assumed %	10%			
D. Cost for Stormwater		$10.00	$8.70	$7.50

Table 8: Summary of cost analysis for other land uses

Land Use	Good $/m^2$	Fair $/m^2$	Poor $/m^2$
	$7.40	$6.50	$5.30
Low Density Residential	$23.50	$22.80	$21.60
Commercial	$13.90	$13.10	$11.90
Apartment	$27.60	$26.80	$25.60
School	$7.40	$6.50	$5.30

Table 9: Unit costs for controls, including opportunity costs for land, 1/99$

ID	LD Res $/m^2$	MD Res $/m^2$	Commercial $/m^2$	School $/m^2$	Apartments $/m^2$	RW15.2 $/m^2$	RW18.2 $/m^2$	RW21.3 $/m^2$
Aspen F	$21.50	$21.50	$21.50	$21.50	$21.50	$21.50	$21.50	$21.50
Aspen G	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30
Driveway 1	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50
Driveway 2	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70
Grass F	$6.50	$6.50	$22.80	$26.80	$13.10	$6.50	$6.50	$6.50
Grass G	$7.40	$7.40	$23.50	$27.60	$13.90	$7.40	$7.40	$7.40
Grass P	$5.30	$5.30	$21.60	$25.60	$11.90	$5.30	$5.30	$5.30
Parking 1	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50
Parking 2	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70
Parking 3	$2.80	$2.80	$2.80	$2.80	$2.80	$2.80	$2.80	$2.80
Parking 4	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
Patio 1	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Patio 2	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Roof 1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Roof 2	$16.10	$16.10	$16.10	$16.10	$16.10	$16.10	$16.10	$16.10
Sidewalk 1	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Sidewalk 2	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Storage	$53.80	$53.80	$53.80	$53.80	$53.80	$53.80	$53.80	$53.80
Street 1	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.60
Street 2	$2.80	$2.80	$2.80	$2.80	$2.80	$2.80	$2.80	$2.80
Street 3	$2.90	$2.90	$2.90	$2.90	$2.90	$2.90	$2.90	$2.90
Street 4	$3.00	$3.10	$3.00	$3.00	$3.00	$3.00	$3.10	$3.00
Swales 1	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30
Swales 2	$64.60	$64.60	$64.60	$64.60	$64.60	$64.60	$64.60	$64.60
Woods F	$8.60	$8.60	$8.60	$8.60	$8.60	$8.60	$8.60	$8.60
Woods G	$15.10	$15.10	$15.10	$15.10	$15.10	$15.10	$15.10	$15.10

Table 10: Unit costs for controls, excluding opportunity costs for land, 1/99$

ID	LD Res $\$/m^2$	MD Res $\$/m^2$	Commercial $\$/m^2$	School $\$/m^2$	Apartments $\$/m^2$	RW15.2 $\$/m^2$	RW19.2 $\$/m^2$	RW21.3 $\$/m^2$
Aspen F	$21.50	$21.50	$21.50	$21.50	$21.50	$21.50	$21.50	$21.50
Aspen G	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30
Driveway 1	$0.60	$2.50	$2.50	$2.50	$2.50	$0.60	$0.60	$0.60
Driveway 2	$0.90	$2.70	$2.70	$2.70	$2.70	$0.90	$0.90	$0.90
Grass F	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70	$2.70
Grass G	$3.70	$4.00	$3.40	$3.40	$3.40	$3.70	$3.70	$3.70
Grass P	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50
Parking 1	$0.60	$2.50	$2.50	$2.50	$2.50	$0.60	$0.60	$0.60
Parking 2	$0.90	$2.70	$2.70	$2.70	$2.70	$0.90	$0.90	$0.90
Parking 3	$1.00	$2.80	$2.80	$2.80	$2.80	$1.00	$1.00	$1.00
Parking 4	$1.20	$3.00	$3.00	$3.00	$3.00	$1.20	$1.20	$1.20
Patio 1	$0.20	$2.00	$2.00	$2.00	$2.00	$0.20	$0.20	$0.20
Patio 2	$0.20	$2.00	$2.00	$2.00	$2.00	$0.20	$0.20	$0.20
Roof 1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Roof 2	$16.10	$16.10	$16.10	$16.10	$16.10	$16.10	$16.10	$16.10
Sidewalk 1	$0.20	$2.00	$2.00	$2.00	$2.00	$0.20	$0.20	$0.20
Sidewalk 2	$0.20	$2.00	$2.00	$2.00	$2.00	$0.20	$0.20	$0.20
Storage	$53.80	$53.80	$53.80	$53.80	$53.80	$53.80	$53.80	$53.80
Street 1	$0.80	$2.70	$2.70	$2.70	$2.70	$0.80	$0.80	$0.80
Street 2	$1.00	$2.80	$2.80	$2.80	$2.80	$1.00	$0.90	$0.90
Street 3	$1.00	$2.90	$2.90	$2.90	$2.90	$1.00	$1.10	$1.10
Street 4	$1.10	$3.00	$3.00	$3.00	$3.00	$1.10	$1.20	$1.20
Swales 1	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30	$32.30
Swales 2	$64.60	$64.60	$64.60	$64.60	$64.60	$64.60	$64.60	$64.60
Woods F	$8.60	$8.60	$8.60	$8.60	$8.60	$8.60	$8.60	$8.60
Woods G	$15.10	$15.10	$15.10	$15.10	$15.10	$15.10	$15.10	$15.10

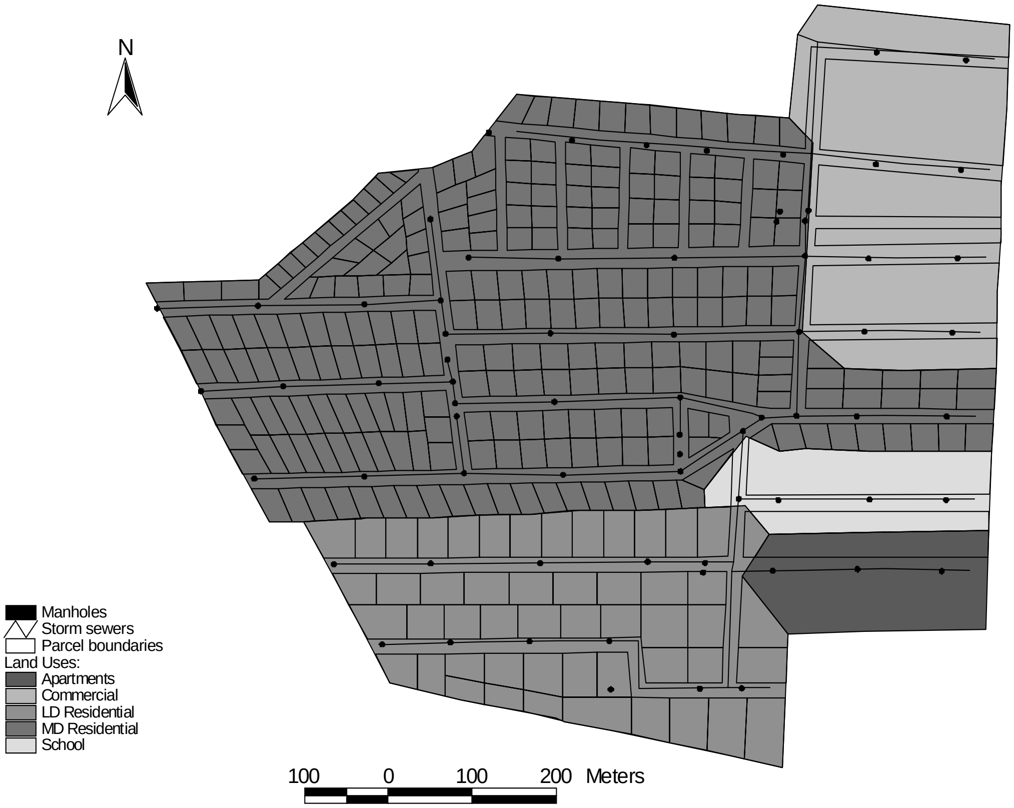

Figure 1: Land use in Happy Hectares (adapted from Tchobanoglous 1981)

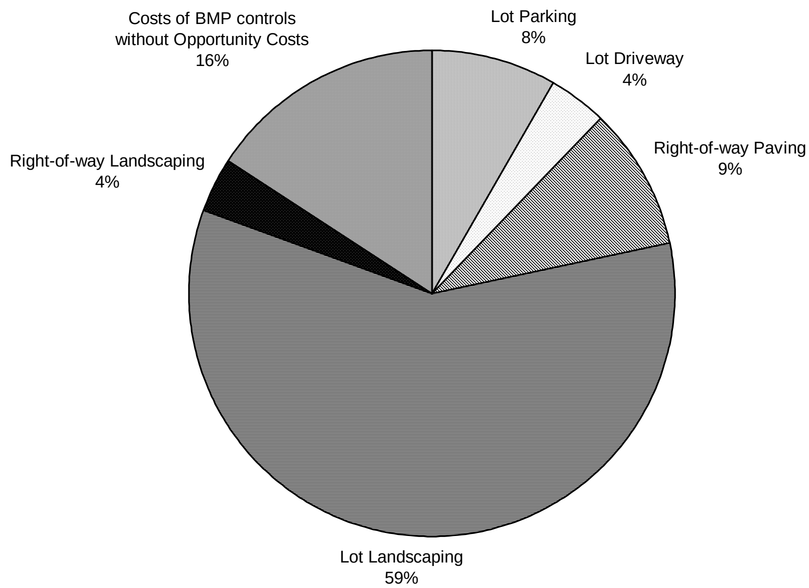

Figure 2: Summary of cost distribution for Happy Hectares, neglecting opportunity costs

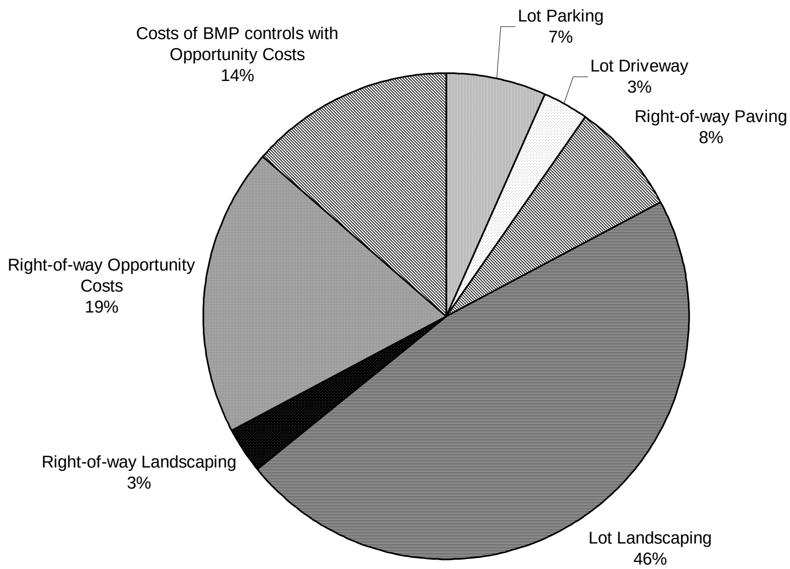

Figure 3: Summary of cost distribution for Happy Hectares, including opportunity costs